LOCAL DISTRIBUTION PATTERNS OF LAND SNAILS IN RELATION TO VEGETATION: IMPLICATIONS FOR RESERVE DESIGN.

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Distribution patterns of land snails amongst forest communities were studied in a 500ha block of State forest in north-east Tasmania. Twelve species were found, four of which were represented by fewer than five individuals. Three of the eight common species were randomly distributed in relation to vegetation. Four others were most abundant in the wetter forest communities, close to drainage lines or adjacent slopes. The remaining common species was most frequently found in the driest community. Retention of streamside reserves when the area is logged would probably protect populations of all land snails. However, a more comprehensive system of reserves including all major vegetation communities would ensure protection of preferred habitat for all species. ☐*Molluscs, land snails, distribution, vegetation community, reserve design, forestry.*

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Because invertebrates, many undescribed, are so diverse, a species-by-species approach to their conservation is totally impractical. Conservation agencies in Australia are now mostly aiming to adopt a strategy of creating reserves to ensure regional representation of vegetation communities. (Brown & Hickey, 1990; Commonwealth of Australia, 1992). It has been argued that a vegetation-based strategy will also cater for invertebrate conservation. Invertebrate assemblages are correlated with vegetation communities (Yen, 1987). However, distributions of many invertebrates are not influenced by changes in vegetation (Richardson, 1990) and species apparently restricted to one vegetation type may not occur throughout it (Hill & Michaelis, 1988; Cameron, 1992).

Mesibov (1993) studied litter invertebrates in north-western Tasmania in a 50 km^2 with rainforest, wet eucalypt forest/woodland and tea-tree *Leptospermum lanigerum* scrub. He concluded that most species ranged across all vegetation types. Distribution patterns of several invertebrate groups across vegetation types at a much drier site in north-eastern Tasmania were here examined. Results for the land snails are presented. Snails were used as they were taxonomically well known, easily identified, numbers of species and densities expected were not excessive, and it was anticipated that they would be influenced by moisture gradients.

STUDY AREA

The study was undertaken on State Forest in north-east Tasmania, in a 500ha block of sclerophyll forest to the north and south-west of Old Chum Dam (41°06'S, 148°03'E). Altitude varied from 100-250m on an underlying geology of Ordovician granite. Average annual rainfall was 978mm. Vegetation was studied by Duncan & Brown (1993) who utilised cover-abundance (Braun-Blanquet) floristic data to distinguish six forest communities:

(1) *Blackwood gully forest*

This forest was associated with gullies and creeklines, often forming a thin corridor along them. Sparse emergents (30m+) of *Eucalyptus obliqua* occurred over a dense secondary tree layer (20-30m) dominated by blackwood (*Acacia melanoxylon*). *Dicksonia antarctica, Olearia argophylla, Pomaderris apetala, Coprosma quadrifida* and *Bursaria spinosa* formed a dense medium to tall shrub-layer. The ground layer was dominated by ferns, including *Blechnum nudum, B. wattsii* and *Polystichum proliferum*. Low light levels reaching the forest floor precluded development of herbaceous species but bryophytes were common.

(2) *Eucalypt gully woodland*

This was adjacent to creeks and gullies where microclimate was slightly less humid and soil moisture higher compared with sites supporting blackwood gully forest. The community comprised woodlands, grading into forest, with *E. obliqua* and occasional *E. viminalis* exceeding 30m. A medium to tall shrub layer and included eucalypts, *P. apetala, Melaleuca squarrosa* and *A. verticillata*. Trunked ferns (*Dicksonia, Todea* and *Cyathea*) were prominent. The ground layer was very dense compared with blackwood gully forest and was dominated by ferns with tall graminoids prominent on poorly drained sites. Herbaceous species were sparse and bryophytes less common than in blackwood gully forest.

(3) *Tall wet sclerophyll forest*

This community occurred on well drained soils on south-facing middle to lower slopes. The upper stratum exceeded 30m and was dominated by *E. obliqua* with *E. viminalis* a minor species. The small tree and tall shrub layer was very sparse. The medium shrub layer (1-5m) was dense and mainly comprised *P. apetala, Monotoca glauca, A. verticillata, Zieria arborescens* and *Coprosma quadrifida*. A dense to very dense ground stratum, dominated by ferns (*Culcita dubia* and *Pteridium esculentum*), was present in some areas. Graminoids, grasses and herbs were sporadic in occurrence.

(4) *Damp sclerophyll forest*

This community was widespread, mainly occupying slopes with south to east aspects. Soils were well drained and had moisture levels intermediate between wet and dry sclerophyll sites. *E. obliqua* and/or *E. amygdalina* were dominant with *E. viminalis* a minor species. The canopy was dense between 20 and 30m. The medium to tall shrub layer was very sparse and mainly comprised *A. terminalis, A. verticillata, Olearia lirata* and eucalypt regeneration. Vegetation below 1m was moderately dense with the relative abundance of sclerophyllous shrubs (e.g. *Pultenaea juniperina, Lomatia tinctoria, Leptospermum scoparium*) and bracken probably reflecting fire history. Graminoids, herbs and grasses were sparse but more prominent than in the wetter forest communities.

(5) *Scrub woodland*

This community was strongly associated with basins and soakages with impeded drainage. *E. obliqua* and/or *E. amygdalina* were dominant. Trees were sparser, lower in height and poorer in form than those in surrounding forest. A dense to very dense medium to tall shrub layer was dominated by *M. squarrosa* with *L. scoparium* and *A. verticillata* also prominent. The ground layer was often dense, being dominated by sedges, ferns and graminoids.

(6) *Heathy dry sclerophyll forest*

This community was widespread in the study area, occupying well-drained middle and upper slopes subject to moderate drought stress. *E. amygdalina* was dominant with *E. obliqua* co-dominant or subdominant. The medium shrub layer was very sparse and the low shrub/ground layer was moderately dense being dominated by bracken (*P. esculentum*) and *L. scoparium* suggesting a history of frequent burning.

METHODS

All 116 plots, each a 10m diameter circle, were located across the study area and stratified to sample the range of vegetation communities (blackwood gully forest, 14 plots; eucalypt gully woodland, 20; tall wet sclerophyll forest, 7; damp sclerophyll forest, 30; scrub woodland, 18; and heathy dry sclerophyll forest, 27). Over 27 days (15 May-23 June 1989), snails were searched (by B.M.) 60 minutes per plot. Areas examined were likely sheltering sites: bark scrolls, bases of ferns, leaf litter including litter built up at the base of trees, loose bark, moss, rotting wood, bases of graminoids (e.g. *Gahnia* and *Lomandra*), stones, tree ferns and woody litter. For each plot, variables recorded were: slope, aspect, overstorey age (mature or regrowth), plant species that contributed significantly to cover or provided shelter for snails for both the shrub layer (>1m) and the ground layer (if ground cover was dense plant species contributing significantly to this cover were given a rating of 2, rather than 1 for just their presence), a shade rating on a 1-3 scale and the type of shelters searched. Snails of many of Tasmania's terrestrial species are small (< 3 or 4mm in shell width or height). Hence, some smaller snails would have been missed on some plots. However, search effort was consistent over the plots. Hence, results from different plots should be comparable.

NUMERICAL ANALYSIS

Ordination of snail data was carried out using semi-strong hybrid multidimensional scaling (SSH) in the PATN software package (Belbin, 1988). The Bray-Curtis coefficient was used as a measure of dissimilarity between samples after standardising data by subtracting minimum abundance of a taxon and dividing by its range to reduce the weighting of abundant taxa. The number of dimensions required for the ordination was assessed by examining stress levels as a function of the number of dimensions from 10 random starts. The chosen number of dimensions was then used in 100 random starts and the one with the lowest stress used. The relationship between the ordination space and the abundances of snail species and the environmental variables were examined using the Principal Axis Correlation (PCC) procedure in the PATN program. The PCC procedure determines the best linear fit between ordination vectors and the variable under consideration (Belbin, 1988). The overall correlation coefficients determined by PCC were tested for statistical significance by using 100 Monte Carlo randomisations of the data set (Faith & Norris, 1989).

The distribution of snails in relation to vegetation communities was examined to see whether the observed patterns could be explained by random processes alone. The Group Definitions module in PATN was used for this analysis. The data for each species were randomised 100 times (Monte Carlo randomisations) and Cramer values calculated. These values are the between-group variance divided by the total variance and range from 0, where no discrimination between groups exist, to 1, where perfect inter-group discrimination occurs. If the Cramer value for the actual data was greater than 95 of the Cramer values from the randomised data sets the observed patterns were considered to represent a non-random distribution amongst vegetation communities. The significance of differences between frequencies of occurrence in different categories was determined using Chi-square tests.

RESULTS

Twelve species of land snail were found on the study area (Table 1). Of the four species for which fewer than five individuals were located, three are very small (less than 3mm) and this may partly explain why few individuals were taken. The fourth species, *Thryasona diemenensis*, however, is conspicuous and unlikely to have been missed. All four *Thryasona diemenensis* were found on one plot at the head of a gully in blackwood gully forest. *Miselaoma parvissima* and *Paralaoma caputspinulae* were found in heathy dry sclerophyll forest and one individual of *Roblinella gadensis* was found in each of eucalypt gully woodland and tall wet sclerophyll forest. These four species are not considered further due to their low frequencies of occurrence.

Two plots yielded no snails and were not included in the ordination. Four dimensions were required to describe the ordination of the plots on the basis of the abundance of snail species. *Caryodes dufresnii*, *Helicarion cuvieri* and *Tasmadelos nelsonensis* appeared to be randomly distributed amongst vegetation communities (Table 1 and Fig. 1). *Cystopelta petterdi* was most abundant in scrub woodland but occurred across the full range of vegetation types being lowest in abundance in blackwood gully forest. *Dentherona subrugosa* was most abundant in blackwood gully forest and occurred in low numbers in other wetter communities. *Elsothera ricei* occurred across all vegetation communities but was most abundant in the gully types. *Tasmaphena*

Species	Total No.	Cramer Value (Significance)	Vector coefficient r (Significance)
CARYODIDAE			
Caryodes dufresnii	50	0.21 (n.s.)	0.36 (n.s.)
CHAROPIDAE			
Dentherona subrugosa	32	0.66 (<0.05)	0.58 (<0.05)
Elsothera ricei	240	0.43 (<0.05)	0.62 (<0.05)
Pernagera officeri	118	0.36 (<0.05)	0.78 (<0.05)
Thryasona diemensis	4	—	—
Roblinella gadensis	2	—	—
CYSTOPELTIDAE			
Cystopelta petterdi	290	0.42 (<0.05)	0.55 (<0.05)
HELICARIONIDAE			
Helicarion cuvieri	406	0.25 (n.s.)	0.82 (<0.05)
RHYTIDIDAE			
Tasmadelos nelsonensis	34	0.25 (n.s.)	0.78 (<0.05)
Tasmaphena sinclairi	13	0.32 (<0.05)	0.32 (n.s.)
PUNCTIDAE			
Paralaoma caputspinulae	2	—	—
Miselaoma parvissima	1	—	—

TABLE 1. Total number of each species of snail found in the study area along with an index of their discrimination between vegetation types (Cramer value) and the correlation coefficient of their vector of maximum correlation within the ordination space.

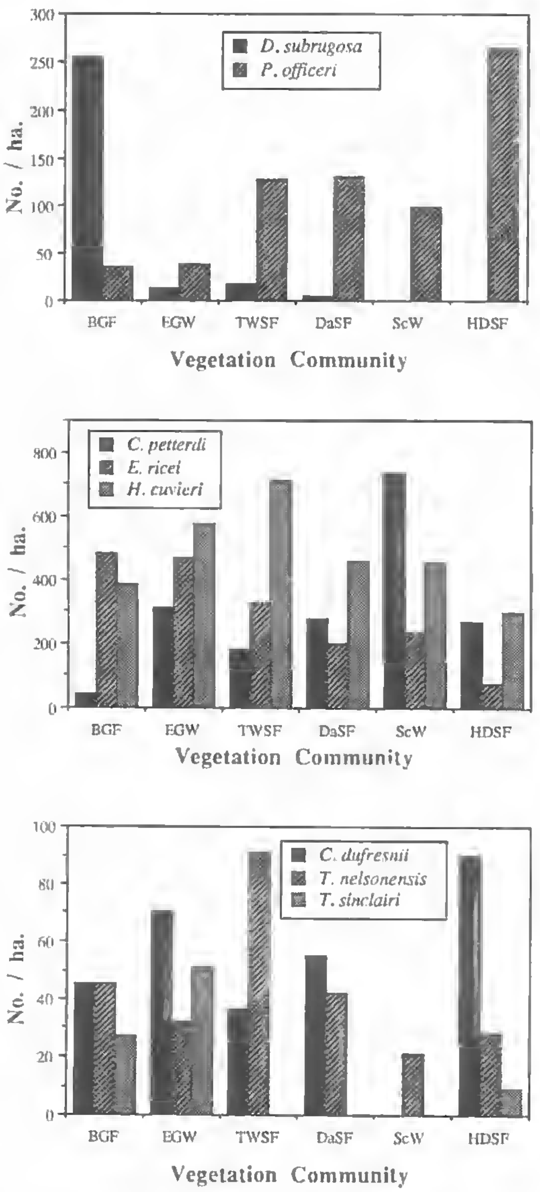

FIG. 1. Density of snail species (No./ ha.) in each vegetation community. BGF = blackwood gully forest, EGW = eucalypt gully woodland, TWSF = tall wet sclerophyll forest, DaSF = damp sclerophyll forest, ScW = scrub woodland and HDSF = heathy dry sclerophyll forest.

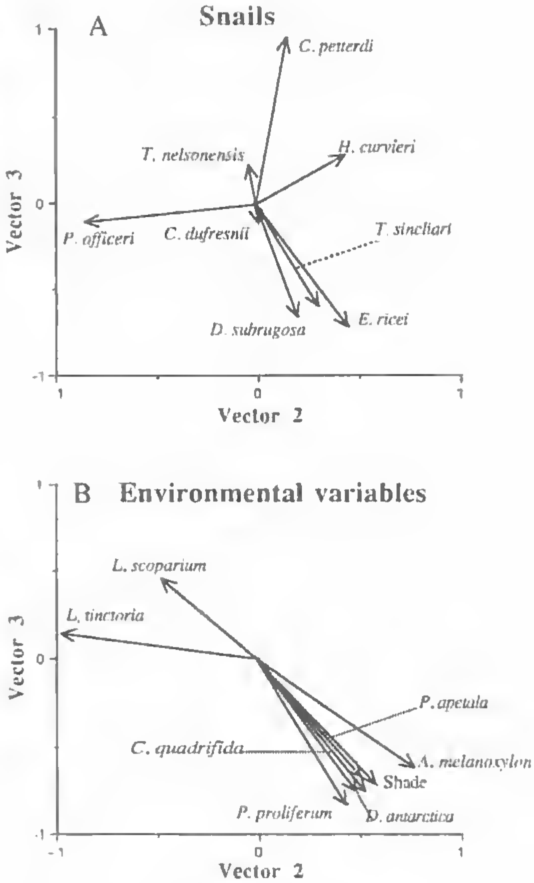

FIG. 2. Directions of vectors of maximum correlation with the ordination space for snail plots for each species (excluding 4 rare species) and for environmental variables showing similar directions to that of the snails. Vectors of similar length and direction indicate co-occurrence of snail species and/or environmental variable in the ordination space.

sinclairi was also most abundant in the gully communities. In contrast, *Pernagera officeri* was most abundant in the driest community, heathy dry sclerophyll forest.

These patterns are confirmed by the ordination (Table 1, Fig 2). *Dentherona subrugosa*, *Elsothera ricei* and *Tasmaphena sinclairi* had similar vectors of maximum correlation within the ordination space. However, the vector for *Tasmaphena sinclairi* was not significant, possibly due to the low abundance of this species. The vectors for environmental variables associated with the wetter vegetation communities (*D. antartica*, r=0.49; *P. apetala*, r=0.35; *A. melanoxylon*, r=0.51; *C. quadrifida*, r=0.40; *P. proliferum*, r=0.44; and shade, r=0.42) had a similar direction to that of *Dentherona subrugosa*, *Elsothera ricei* and *Tasmaphena sinclairi*. For *Dentherona subrugosa* and *Elsothera ricei* the proportion of plots containing these snails variables was significantly greater (Chi-squared tests) where the above mentioned plants were present (or where shading was greater) than for those plots were they were absent (or where shading was low). This was also the case for *Tasmaphena sinclairi* but sometimes not significantly so, probably due to fewer specimens. The vector for *Pernagera officeri* was similar to that for *L. tinctoria* (r=0.49) and to a lesser extent *L. scoparium* (r=0.44) (Fig. 2). Neither plant species occurred in the gully communities but ranged across other vegetation types. *L. scoparium* was the main low shrub species in the driest community, heathy dry sclerophyll forest. The proportion of plots containing *Pernagera officeri* was significantly greater where *L. tinctoria* and *L. scoparium* were present than for these plots where these plants were absent. *Caryodes dufresnii* was randomly distributed in the ordination space and in relation to vegetation communities. *Cystopelta petterdi* and *Helicarion cuvieri* had vectors in the ordination space that were dissimilar to all other species and to each other (Fig. 2) and these species' vectors did not closely relate to any vectors of the environmental variables. *Helicarion cuvieri* had the strongest vector of maximum correlation in the ordination space. However, its pattern of distribution appeared not to relate to vegetation. This was also the case for *Tasmadelos nelsonensis* which had the next strongest vector.

An examination of occurrence of snail species in different types of shelters (= microhabitat usage) reinforced the pattern indicated by vegetation. For example, *Dentherona subrugosa* was restricted to the wetter gullies and was significantly associated with tree fern (*D. antartica*) heads as a shelter site. Tree ferns in turn were restricted to wetter gullies.

DISCUSSION

Vegetation patterns in the study area are strongly related to topography via its influence on drainage (and thus soil moisture), soil fertility and protection from fire (Duncan & Brown, 1993). Better soils with a high organic content occur on the lower slopes and in gullies, and the shallower, more sandy soils occur on the ridges and steeper slopes. The distributions of three snails (*Caryodes dufresnii*, *H. cuvieri* and *Tasmadelos nelsonensis*) were not related to these vegetation patterns and all three were widespread across the study area. Distributions of other species were related to vegetation patterns but none were restricted to one vegetation type. The single site occurrence of *Thryasona diemenensis*, in blackwood gully forest, is puzzlingt as it is very common in north-east Tasmania in a wide variety of wet habitats and even some dry areas (K. Bonham, pers. comm.).

Results here are similar to those of Mesibov (1993) on litter invertebrates in north-west Tasmania in that most species ranged across most of vegetation types. Both studies also found a minority of species were restricted to one or very few of the range of vegetation types examined. Mesibov's (1993) study also found distinct differences in densities of some species in different vegetation types, as our study did.

Because many invertebrates have restricted distributions, any generalised reserve system for invertebrates would need to include reservation of habitat at a localised level to supplement a regional vegetation based reserve system. Sampling of vegetation types and/or landforms should be undertaken comprehensively in such a localised reserve system as well as at a broader regional scale. Our study area occurs in State Forest. Until recently, the only systematic reservations at a local level in State Forests were streamside reserves, designed to protect water quality. These reserves extend from 20 to 40m either side of streams depending on stream and protect all streams with a catchment greater than 50ha (Forestry Commission, 1993). These reserves are thus biased towards wetter communities in gullies and areas of impeded drainage. Streamside reserves in the present study area would probably protect populations of most species, since most are widespread and/or have wetter forest types as their favoured habitats. However, *Pernagera officeri*, which reaches its highest densities in the driest vegetation type, would be poorly represented in such reserves. The preferred habitats for all species should be included within reserves. Retention of 100m-wide strips (referred to as wildlife habitat strips), which also include areas of slope and ridge and hence more comprehensively sample vegetation types at a local level, has therefore been introduced in Tasmanian State Forests (Taylor, 1991). Such measures should better provide for the conservation of invertebrates.

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